Coalbed Methane Technology and Development

PETROTEL INC.

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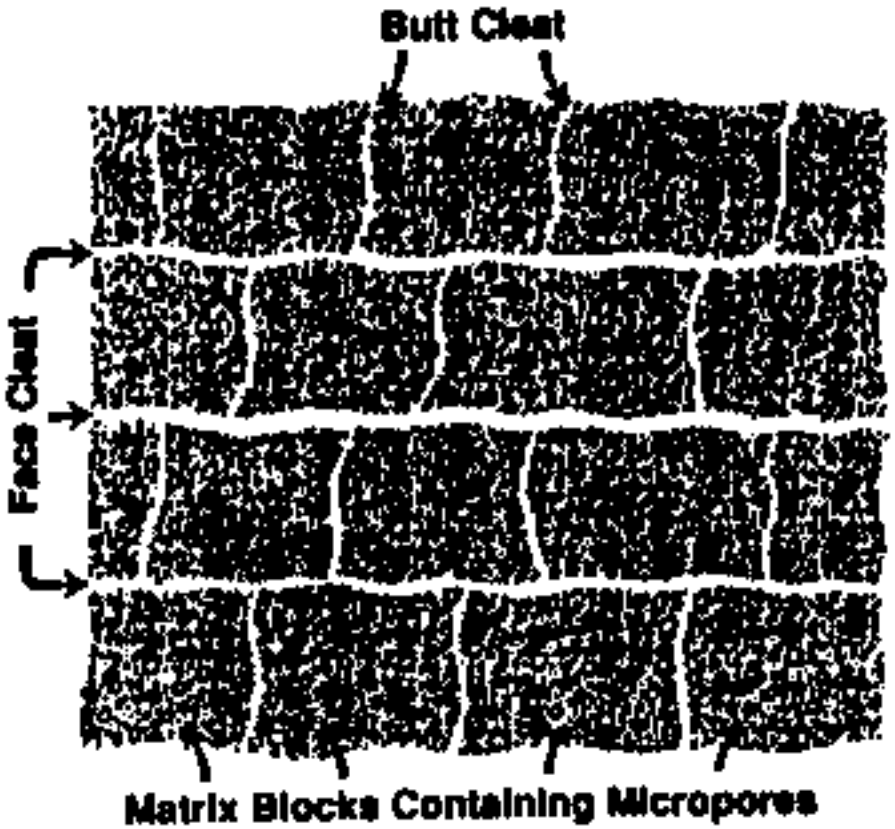
President and CEO

What is Coalbed Methane?

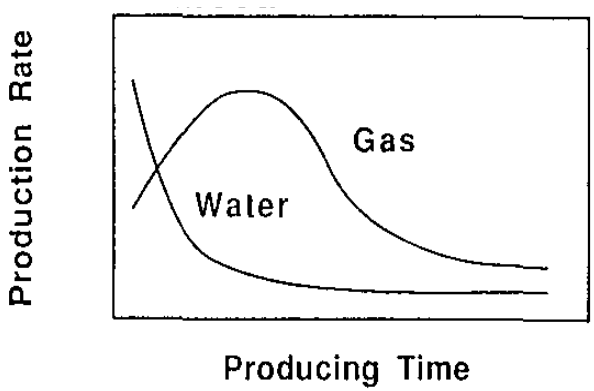
- The process of coal formation is known as coalification; it also produces large quantities of by-product gases (methane, CO_2, N_2..)
- Methane is found in coals either adsorbed on the coal surface,or as free gas in fractures and large pores, or dissolved in ground water.
- Original methane content - 200 to 600 ft^3/ton

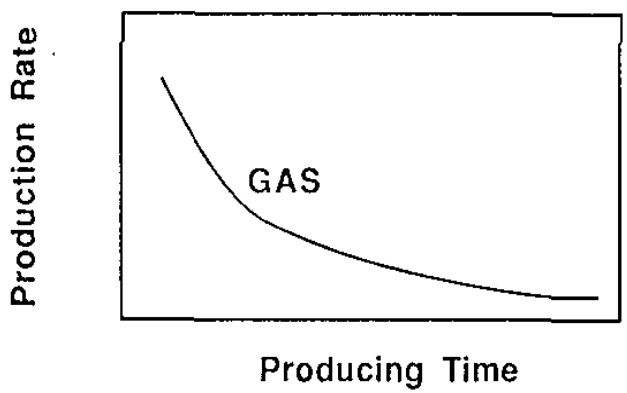
What is Coalbed Methane?



Difference between conventional gas reservoir and coalbed methane reservoir

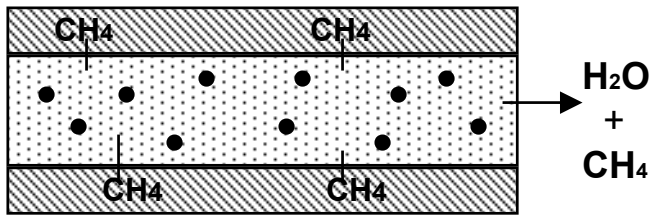
	Coals	**Gas Sands**
source	coalification	migration from source
gas storage	adsorption	free gas under pressure
flow path	fracture	interconnected porosity
prod. mech.	diffusion,desorption & Darcy flow	Darcy flow





Recovery Mechanism

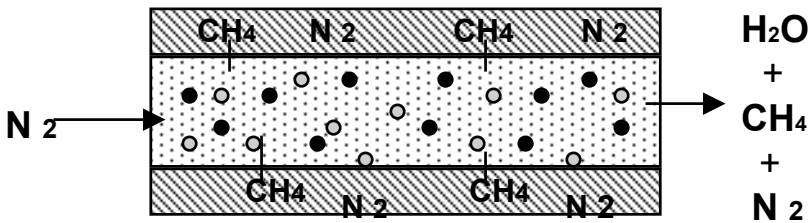
Primary (SPE 20733, 'Validation of 3D Coalbed Simulation', G.W. Paul, W.K. Sawyer, R.H. Dean)



- **Reduce Cleat Pressure by Producing Water**
- **CH_4 Desorbs from Matrix and Diffuses to Cleats**
- **CH_4 and H_2O Flow to Wellbore**

Enhanced Methane Recovery (EMR)

(SPE 24363, 'Modeling Coalbed Methane Production with Binary Gas Sorption', L.E. Arri, Dan Yee, W.D Morgan and M.W. Jeansonne)



- **Injected N_2 in Cleats**
- **N_2 Adsorbs in Matrix**
- **Reduce Partial Pressure of CH_4**
- **CH_4 Desorbs from Matrix and Diffuses to Cleats by Sorption Displacement & partial pressure reduction**
- **CH_4, N_2 and H_2O Flow to Wellbore**

Coal as Reservoir Rock!

$\phi = 5 \pm \%$

$K_{air} = 0.1$ to 10 md

<u>Critical Coal Reservoir Parameters</u>

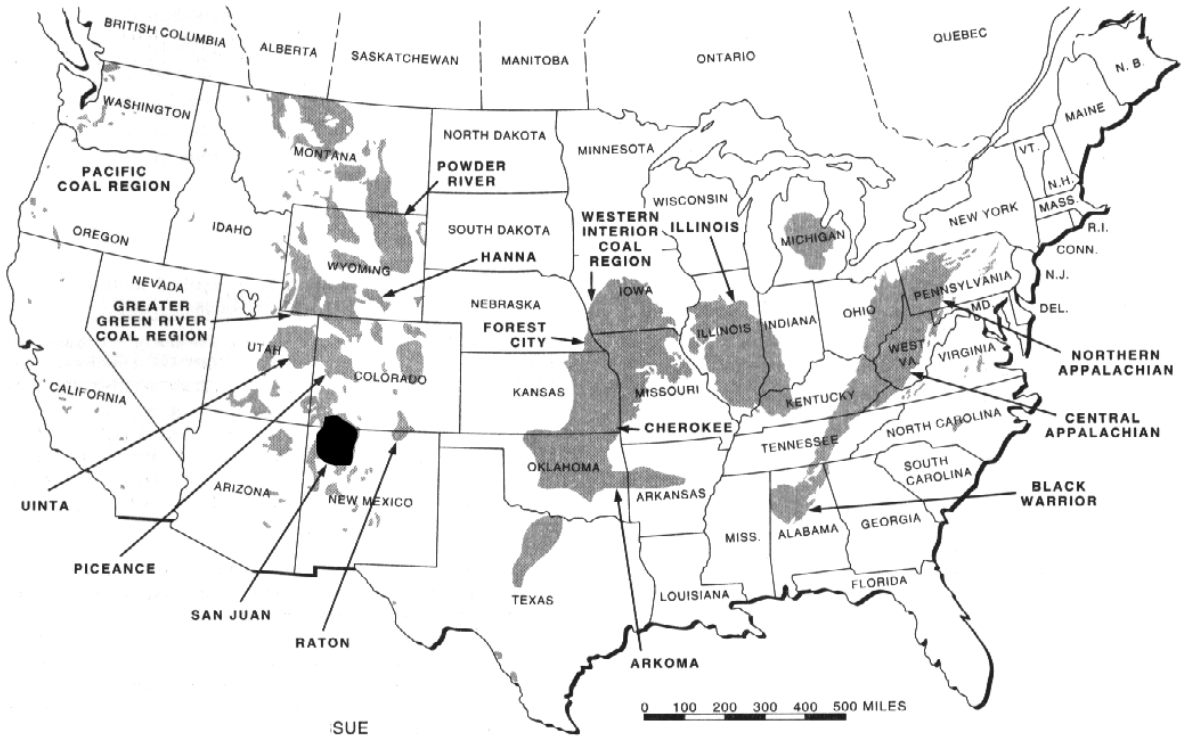
Methane Content

500 SCF/ton equivalent to 2500 psig gas reservoir

Cleat Development

major gas migration pathway

Location of the San Juan Basin



San Juan Basin Coalbed Methane

Remaining Reserves 280 Billion M^3

Current Production 70 Million M^3/D

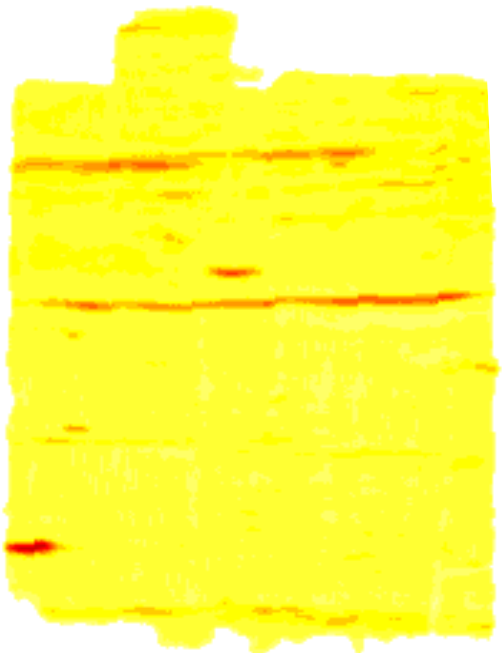
Number of Producing Wells 3,500

Number of Operators 90

Top 20 Operators Produce 90% of Production

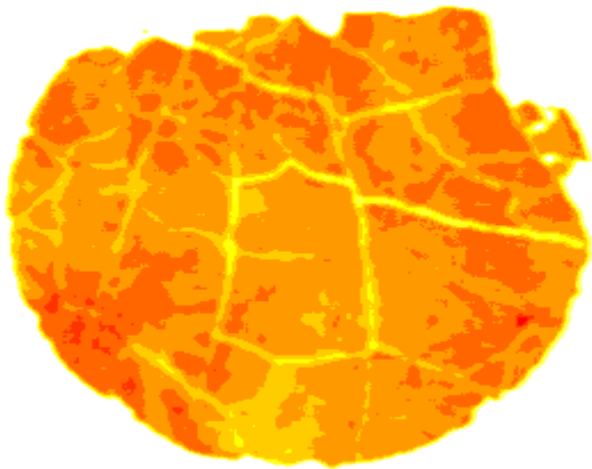
Fruitland Coal Types: Bright Banded Coal

Well cleated, abundantvitrain, low density, low ash (< 15%)



CT image

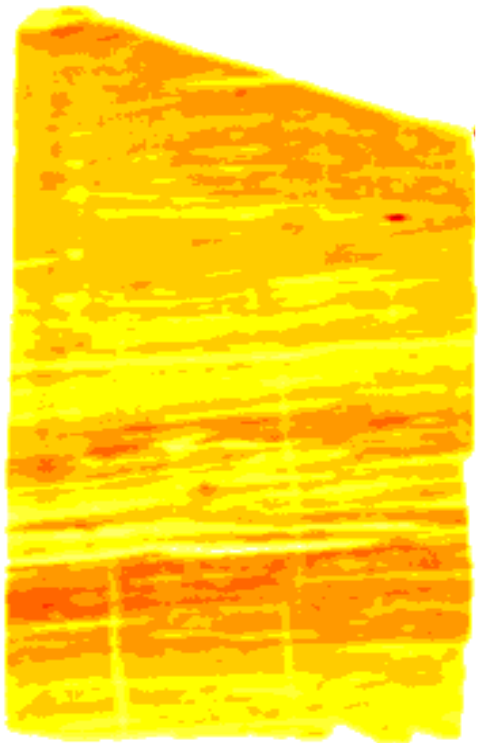
Core photo



CT axial image

Fruitland Coal Types: Dull Banded Coal

Some cleating; moderate vitrain, density, and ash (15-40%)



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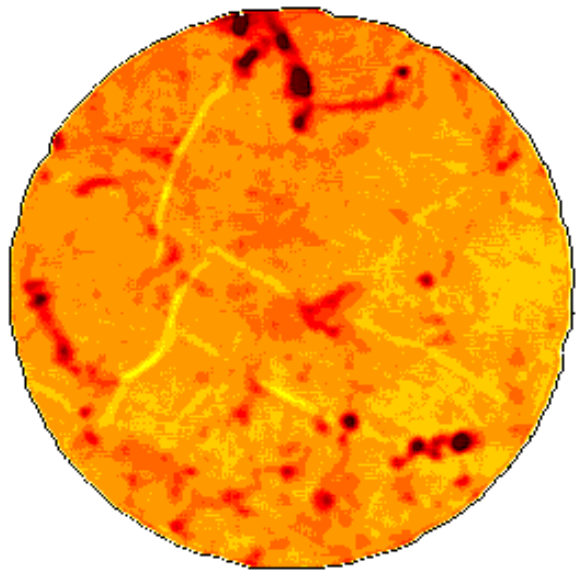

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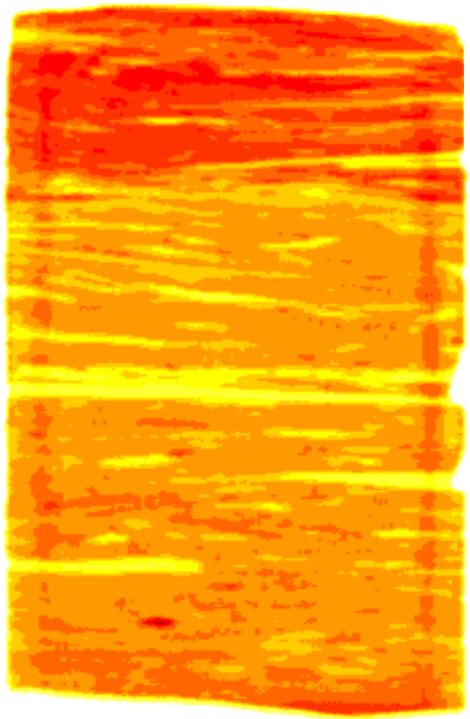
Fruitland Coal Types: Non-banded Coal

Poor cleating, low vitrain, high density, high ash (40-80%)



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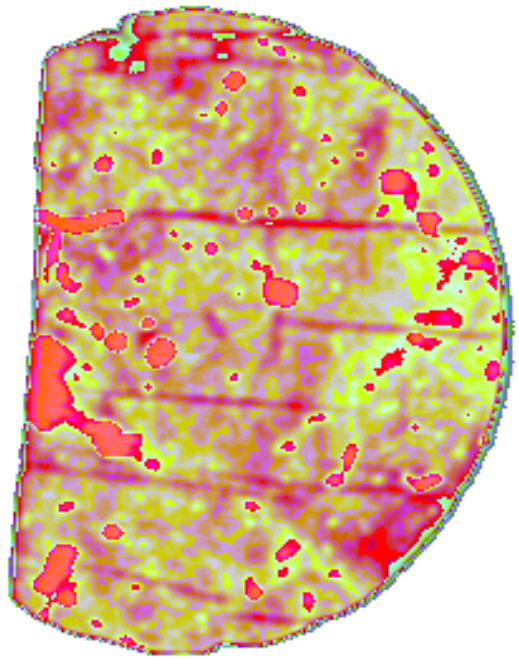

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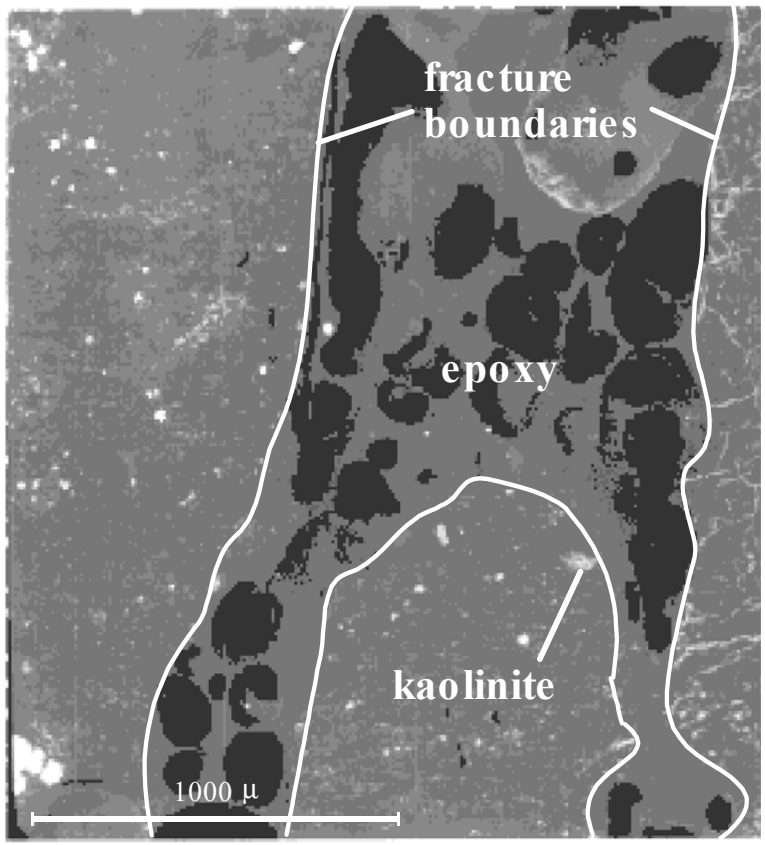
Relationship of Cleating to Productivity

- Low ash, well-cleated coal is the best gas resource
- Bright banded coals have best potential for high perm
- Cannot relate degree of cleating directly to perm
- Cleats may not be permeability conduits
  - Closed by local stresses
  - Plugged by fracture filling
- Cleats may have enhanced permeability
  - Joints and faulting increase connectivity

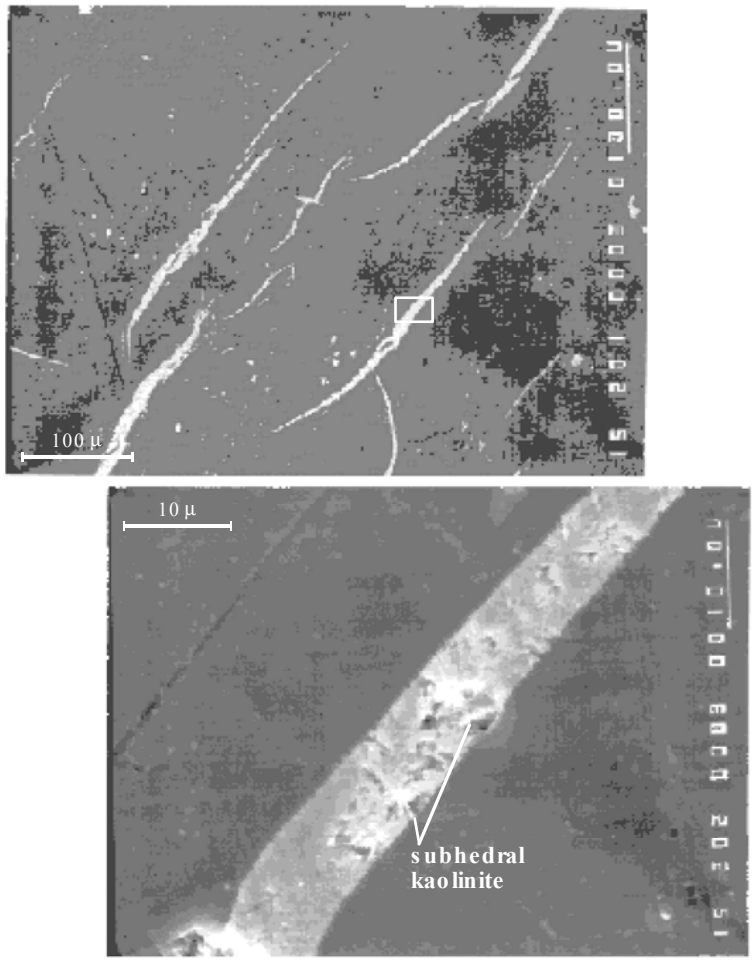
Enhancement of Permeability by Fracturing



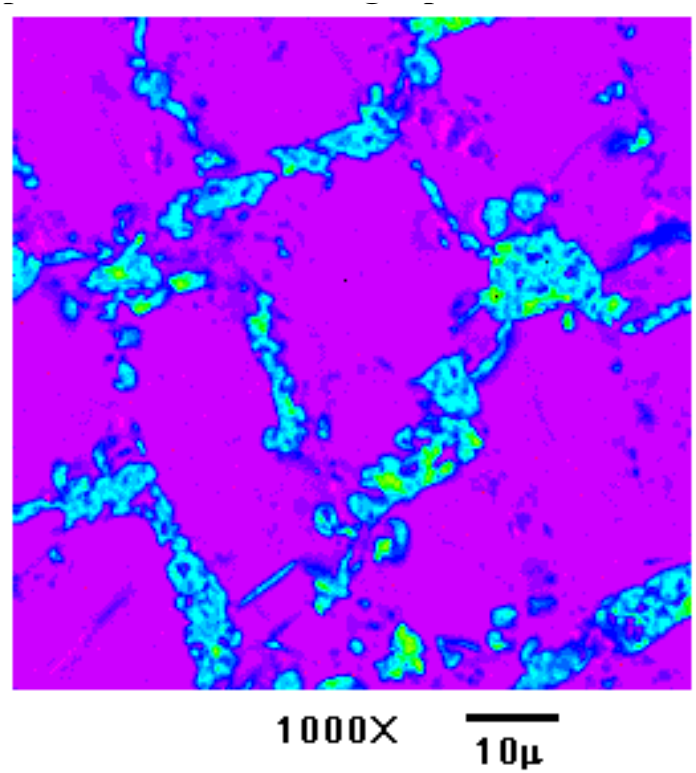
Electron microprobe photo

Core jointing photo

Reduction of Permeability by Mineralization



Kaolinite filling cleats



Plugged cleat network

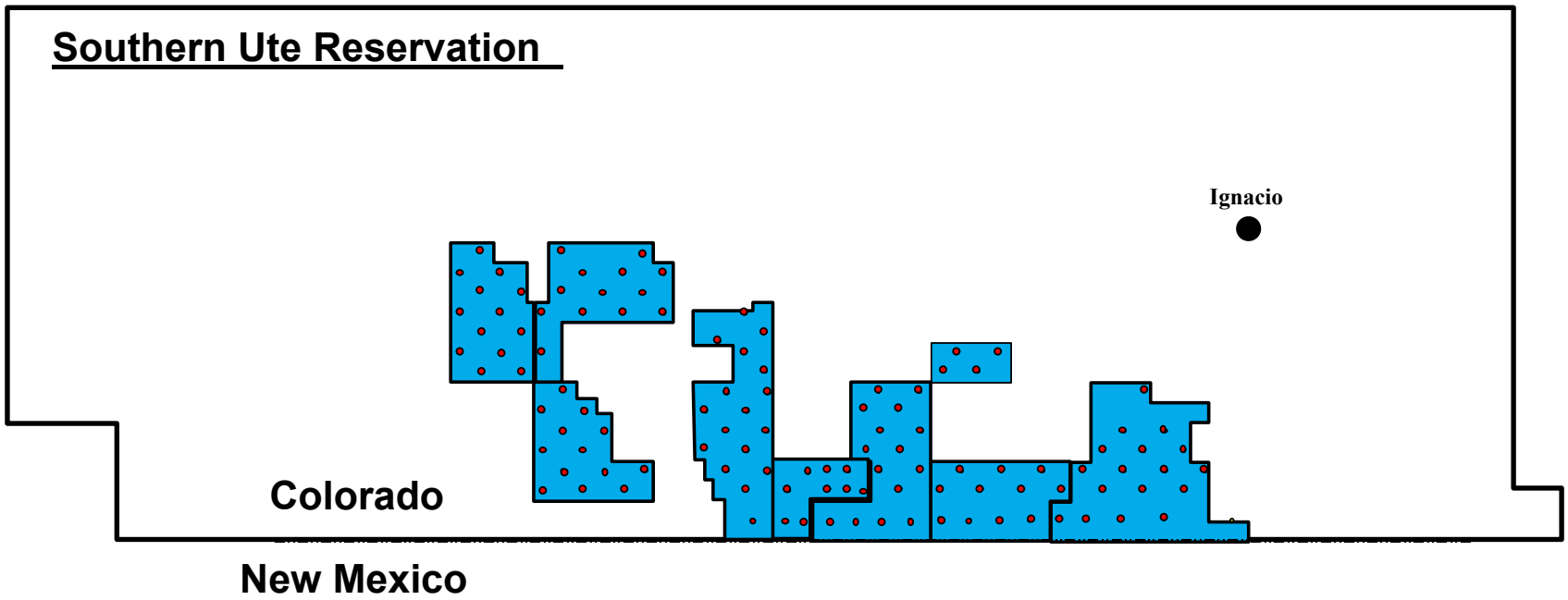
Digital Log Data Base

Basin Wide Data Base

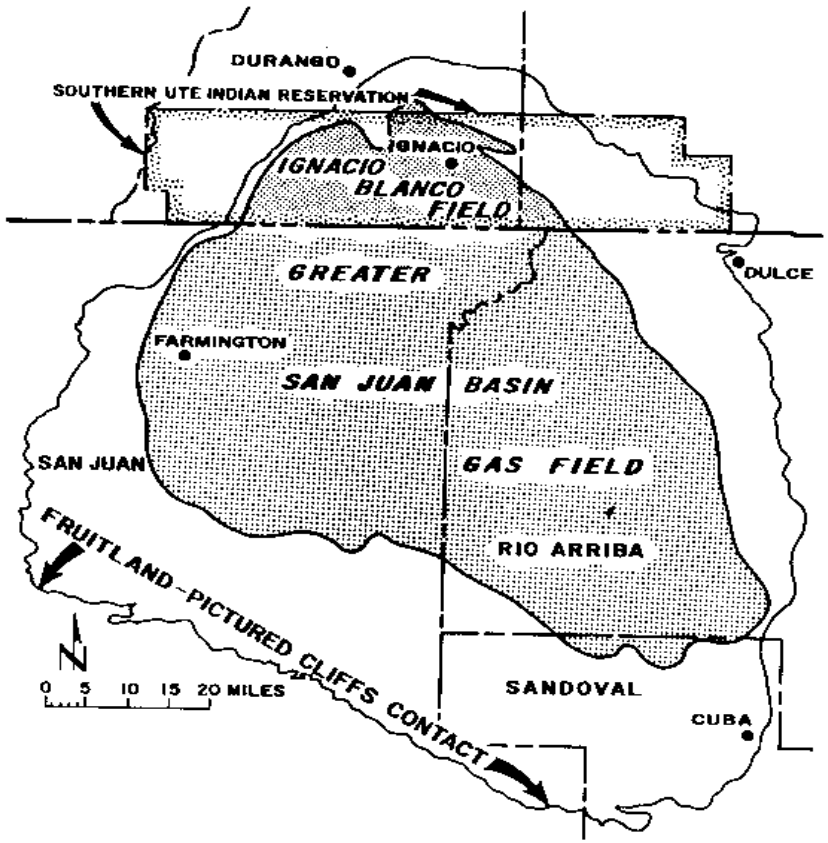
Enhances Interpretation

- Digital Log Analysis
  - Lithology Correlation Based on Gamma Ray and High Resolution Density Logs
  - Gas Content Correlation a Function of Temperature, Pressure and Ash Content
- Facilitates Cross Sections/Fence Diagrams
- Resource Mapping (Gas in Place)

Ignacio Blanco Fruitland



Ignacio Blanco Gas Field



Location Map

Animas Ss		
Kirtland	Upper Shale	
	Farmington Ss	
	Lower Shale	
Fruitland Coal		
Pictured Cliffs Ss		●
Lewis Shale		
Mesaverde	Cliff House Ss	
	Menefee Shale	
	Point Lookout Ss	●
Mancos	Upper Shale	
	Lower Shale	
Greenhorn Limestone		
Graneros Shale		
Dakota Ss		●
Burro Canyon Ss		●

Cretaceous Strat Column

Ignacio Blanco Fruitland

Central Treating Sites 8

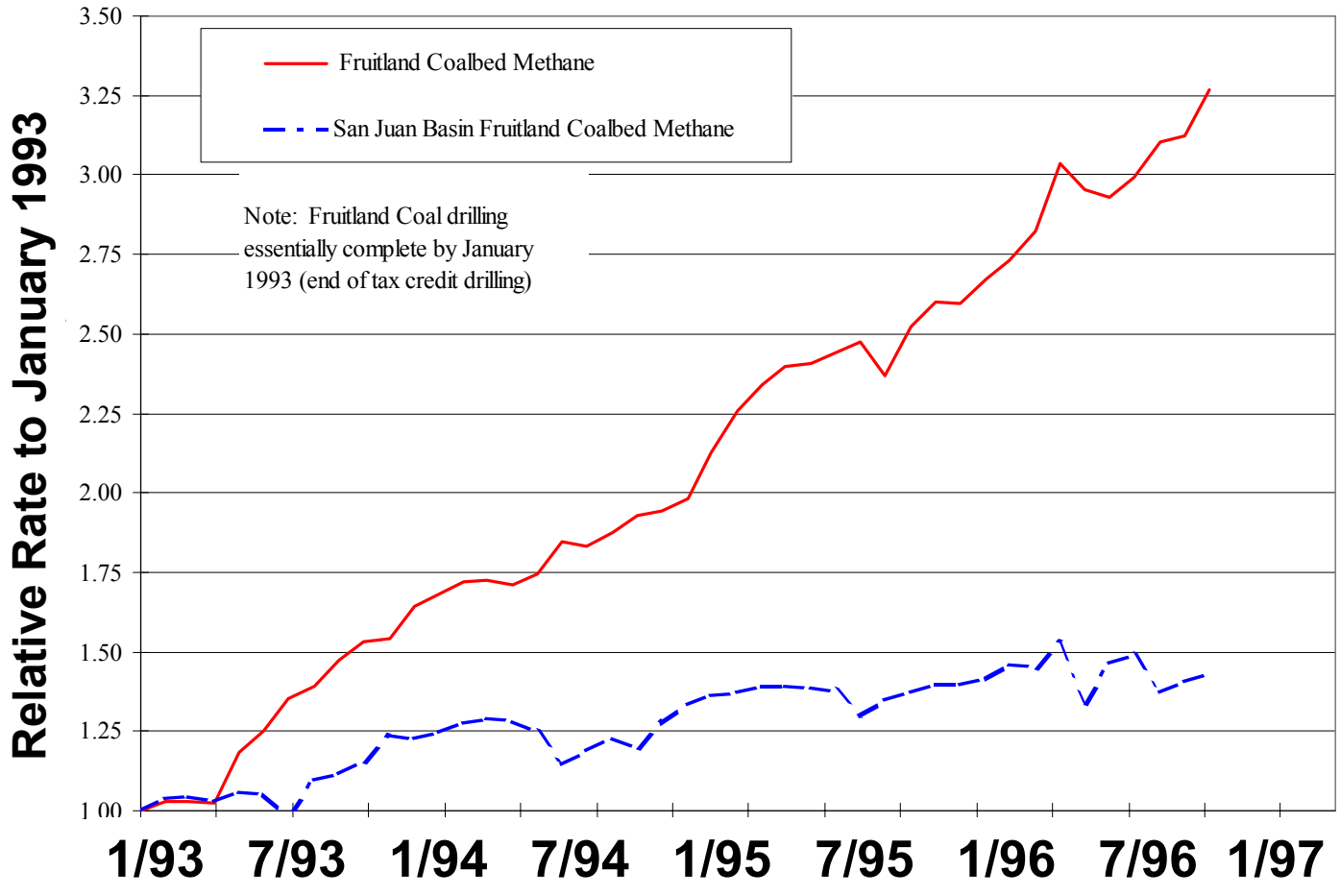
- Gas Lift
- Low Pressure Gas Gathering
- Water Gathering

Wells 109 Producers

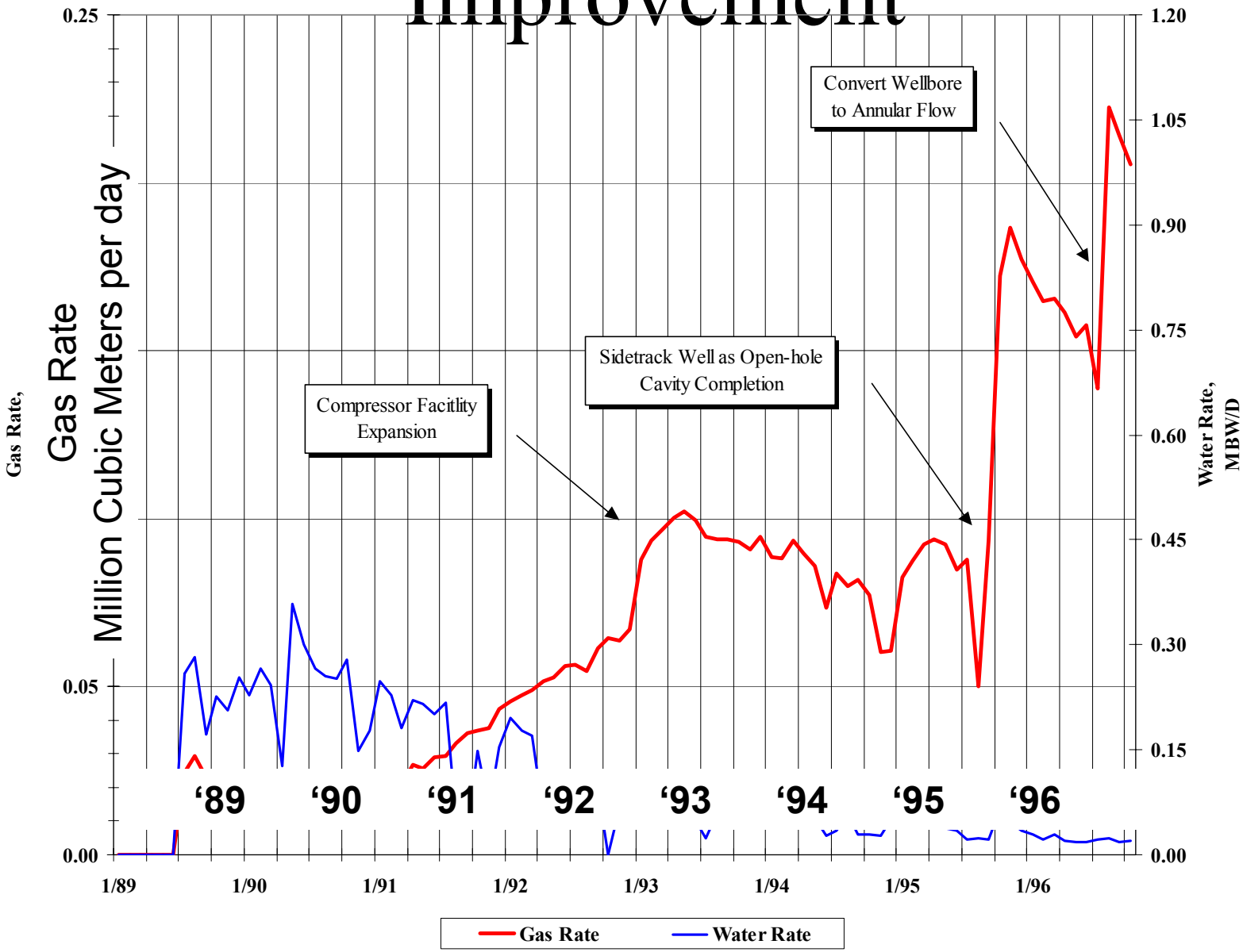
5 Water Disposal Wells

	1995	1996
Production	3.7 Million M^3/D	5.0 Million M^3/D
Compression	24,000 HP	34,500 HP
Automated		

Field Development Optimization



S. Ute 14-3,32-10 Production Rate Improvement



Key Components of Production Optimization Program

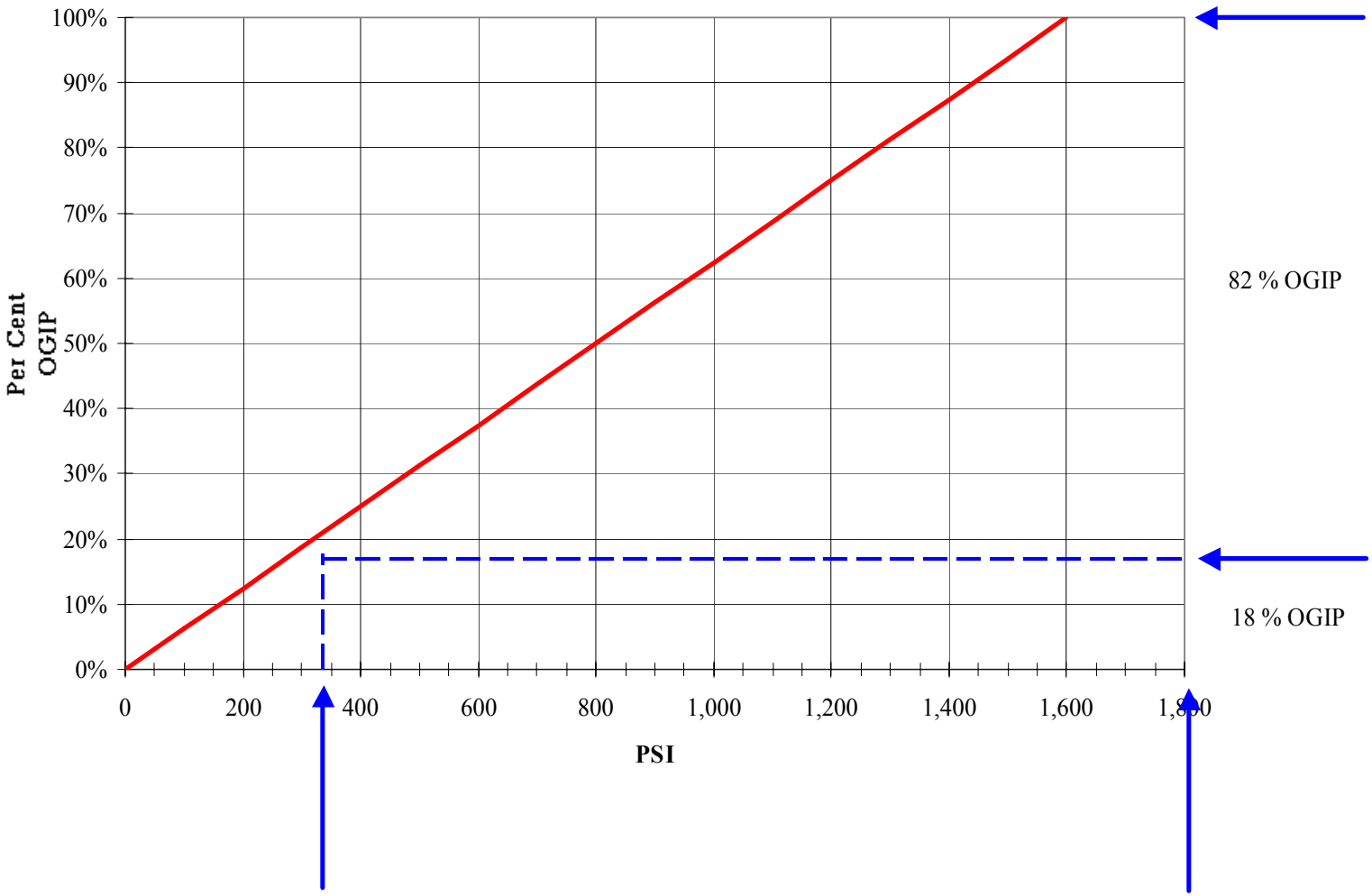
Gathering System Work

- Compression Additions
- Trunk System Pipeline Looping

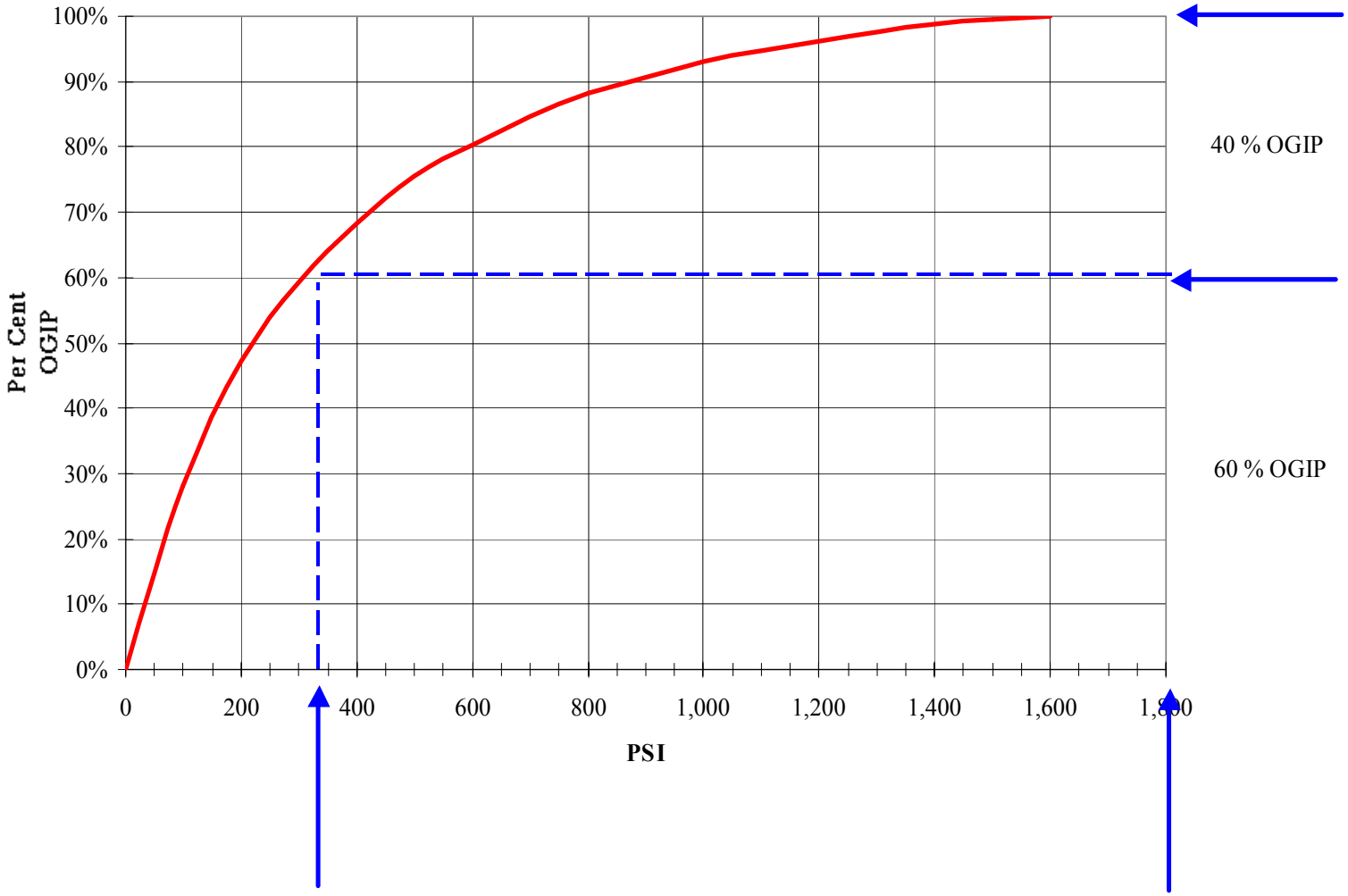
Remedial Well Work

- Sidetrack/Casing Mill-Out Open Hole Completions
- Re-Stimulation of Poor Performing Wells
  - Improved, Low Damage Designs
- Tubing Upgrades
- Well Site De-Bottlenecking

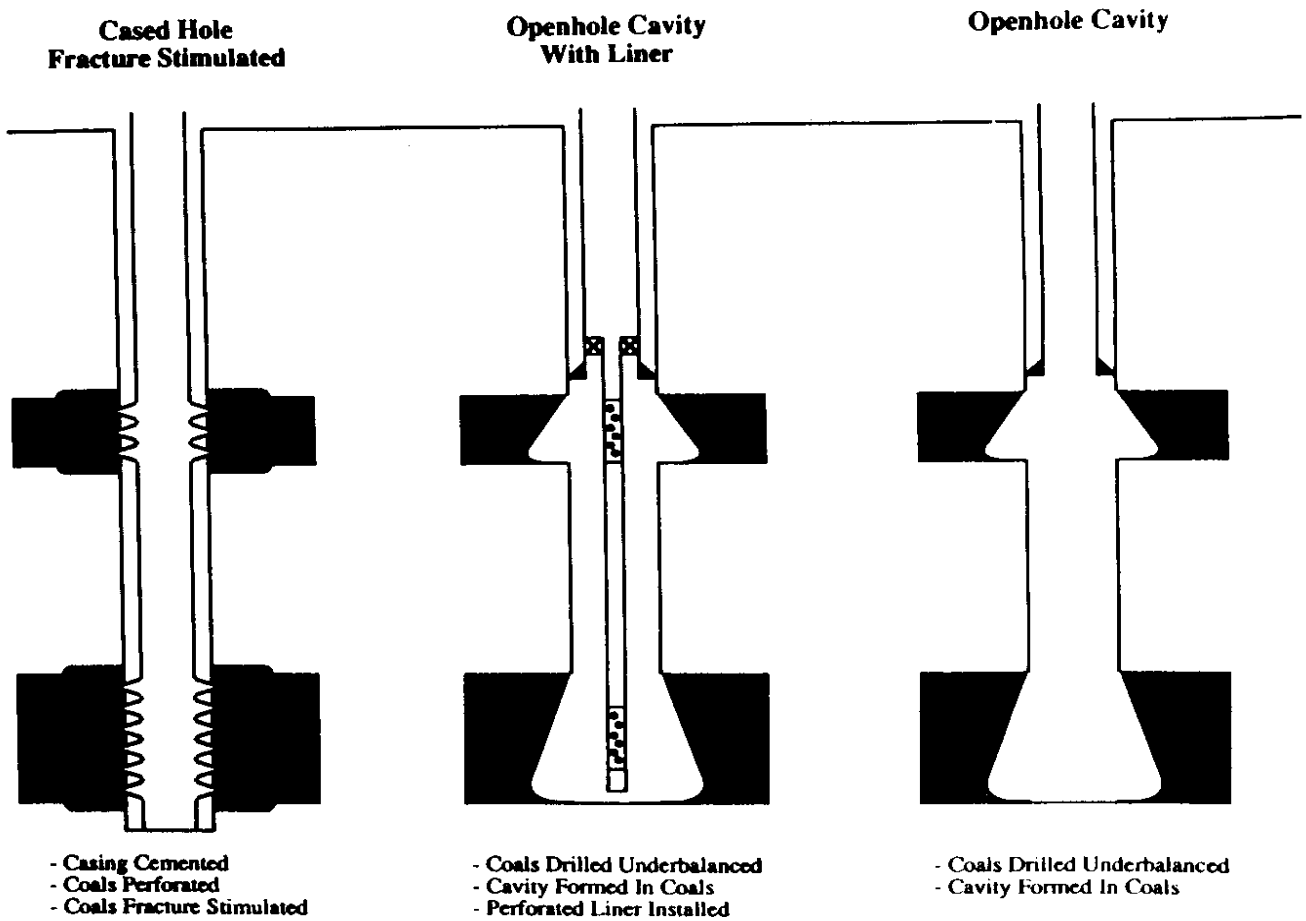
Conventional Well Pressure vs GIP



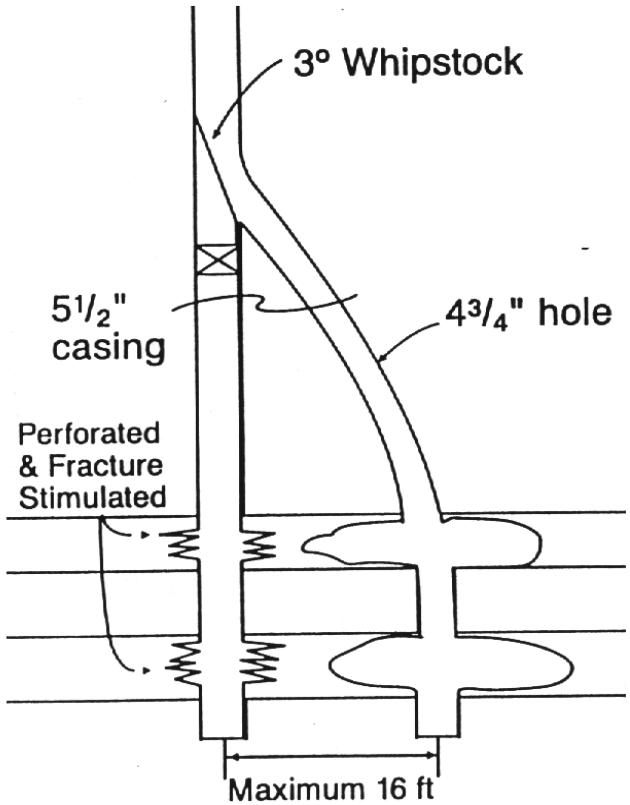
Coalseam Well Pressure vs GIP



Coalbed Methane Well Completions



Side Track to Open Hole Cavity Completion



Coalbed methane data (gas in place)

- Gas in place calculation
  - Net coal thickness
  - Effective porosity of the coal (cleat system)
  - Initial water saturation in the cleat system
  - Initial fluid pressure
  - Gas content of the coal
  - Coal density
- Total gas in place = free gas-in-place + sorbed gas-in-place

Reserve Determination - Minimal Production History

- Gas-In-Place Determination
  - Coal Volume - Mapping Program Integration of Digital Data Base
  - Gas Content Correlations
    - Based on Core Analysis
    - Function of Pressure, Temperature and Ash Content
- Recovery Factor Based on Numerical Simulation

Reservoir Simulation

- World Class Numerical Simulators
- Predictive Studies
  - Highly Dependent Upon Reservoir Description
    - Complex Water/Gas Relative Permeability
    - Stratified, Heterogeneous Reservoir Rock
    - Variable Permeability - Stress, Degassing
- Good Tool to Evaluate Historical Performance

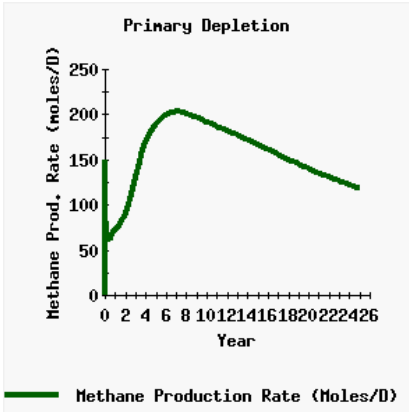
Simulation - Numerical Model

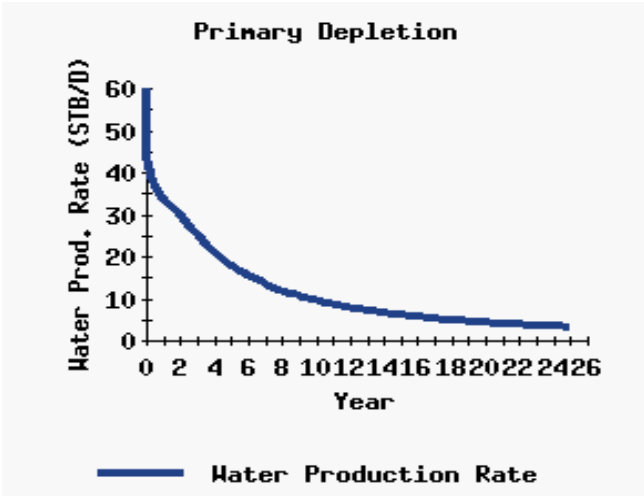
- Model as a dual porosity system
  - fracture : cleats
  - matrix : coals
- Use the Langmuir isotherm (primary) / the extended Langmuir isotherm (EMR) for simulating the adsorption/desorption

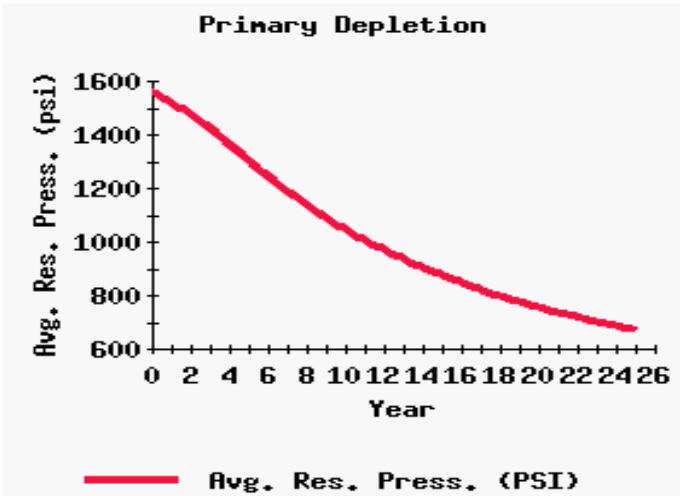
Simulation - Pilot Studies

- 1/4 of 320 acres
- 2D areal 10 x 10
- Permeability 5 md
- Coal Thickness 37. ft
- Coal Density 1.33 g coal/cc coal
- Cleat Porosity 0.1%
- Initial Pressure 1561 psi

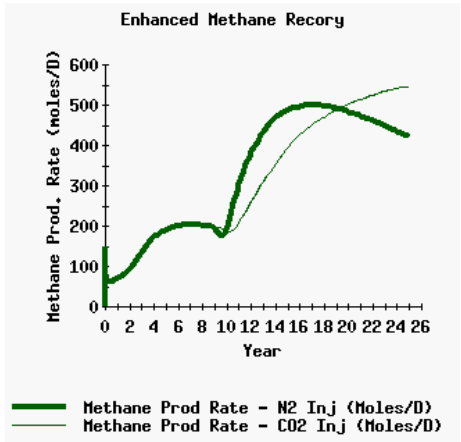
Simulation - Primary

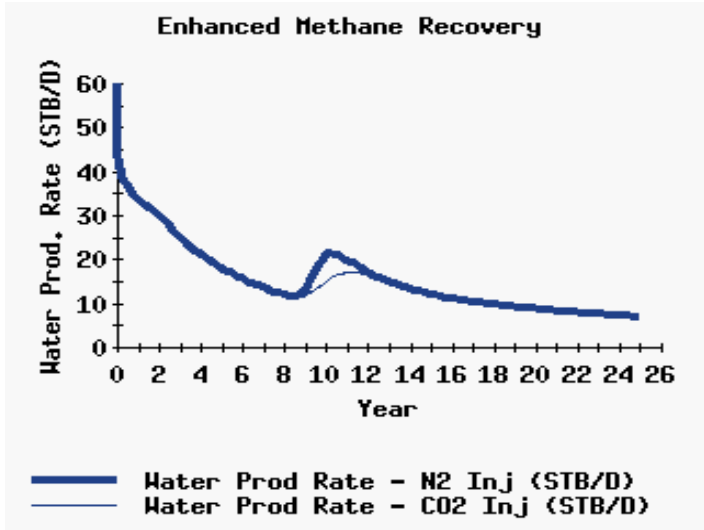


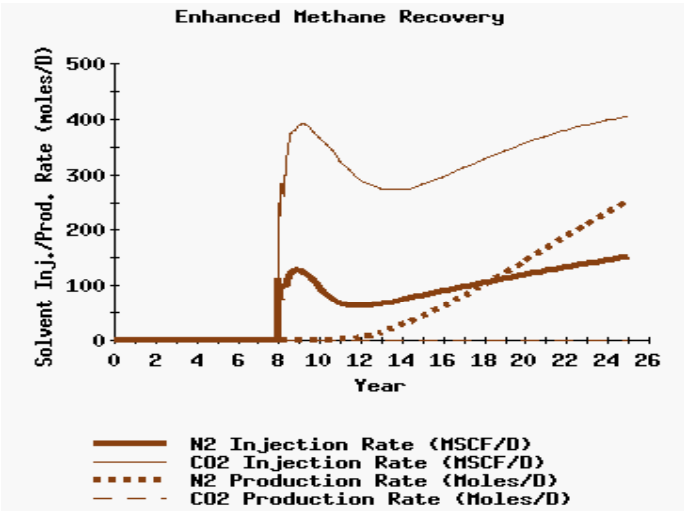


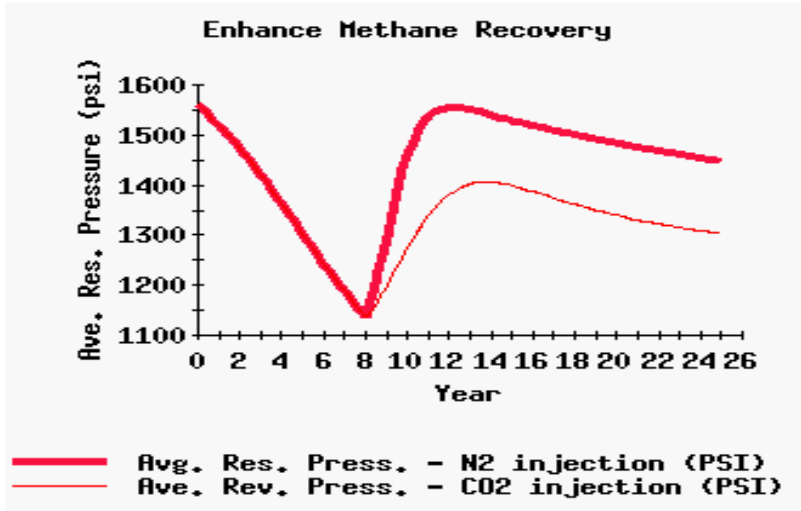


Simulation - Enhanced Methane Recovery
(N2 vs. CO2 injection)









Artificial Lift

- Gas Lift (Preferred Method)
  - Flexible to Widely Varying Water Rates
  - Requires Gas (Potential Problem for Pilot)
  - Not Adversely Impacted by Solids Production (Coal Fines and Frac Sand)
  - Convert Gas Lift Compression to Sales as Wells Ramp and Dewater

- Beam Pump
  - Frequent Maintenance (Solids)
  - Gas Interference
  - Common
  - Low Bottomhole Pressure

Artificial Lift (Continued)

- Progressive Cavity Pump
  - Better Tolerance to Solids than Beam Pump
  - Low Bottomhole Pressure
- Electric Submersible Pump
  - High capacity
  - Gas Interference

Horizontal Wells

- Design
  - Horizontal wells can be designed to maximize the intersection with the fracture network in the coals thus enhancing productivity
- Risks
  - Formation collapse
  - High pressure drop in the wellbore
  - Cost

Conclusions

- Bright banded coals have the highest quality
  - well cleated, low density, low ash (<15%)
- Others coals (15-80% ash) have poorer quality
  - need to understand their gas content, permeability
- Carbonaceous mudstones (>80% ash) are non-reservoir
- Permeability is enhanced by faulting
- Permeability is reduced by cementation
- Bulk density tool does not capture reservoir heterogeneity
  - need to try a microlog, borehole televiewer, or FMI

Conclusions

- Production of CBM from San Juan Basin is 6.8 MM m^3/day
- Production from CBM wells can be increased by:
  - Sidetracks and open-hole completions
  - Stimulation of poorer performing wells
  - Upgrades to gathering and compression systems
- Technology is essential for success:
  - World-class geological evaluation
  - numerical simulators and characterization tools
  - Completion design and execution
  - CT density and microprobe for coal characterization